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EV 195836068 US

DATA RECORDER

BACKGROUND OF THE INVENTION

The invention relates to data recording, and more particularly, to an apparatus for recording linear and angular velocity.

Sudden changes in linear and rotational velocity are often dangerous. The study of these changes is important to design safer methods and devices for transporting objects and people.

Compact data recorders, such as the one described in U.S. Patent No. 6,122,959, have proven invaluable in collecting linear velocity and acceleration information. The recorders are small enough to be used in field tests. The data recorders use an arrangement of linear accelerometers or a single triaxial accelerometer to monitor changes in velocity. While compact data recorders are well suited to tracking changes in linear movement, they are not as effective as recording rotational movement.

Real world motion is rarely purely linear. Often an object will spin or rotate about an axis as well as move linearly. In some instances, the angular velocity of an object causes more damage than its linear acceleration. For example, if a motor vehicle begins to spin violently, the high rotational velocity endured by an occupant may cause severe brain injury. Thus, to understand the forces associated with motion, recording of both angular velocity and linear acceleration is important.

A compact data recorder capable of recoding angular velocity, linear velocity and linear acceleration would thus be highly desirable.

SUMMARY OF THE INVENTION

These problems are overcome by a data recorder capable of measuring both angular velocity as well as linear velocity and linear acceleration. Such a compact data recorder includes three linear accelerometers and three angular rate sensors contained within a housing. Each angular rate sensor is arranged to monitor motion about one of three axes, while each of the linear accelerometers is also arrange to monitor motion along one of the three axes. A processor and memory are provided to record the angular velocity, the peak linear acceleration and linear velocity of the data recorder.

The angular rate sensors provide data related to the motion of the data recorder about the axes, while the linear accelerometers provide data about movement along the axes. The data recorder thus records motion in all six degrees of motions, producing a more accurate representation of the movement. Because the data recorder has a small footprint and weight, the data recorder can be used in a variety of different situations.

These and other objects, advantages and features of the invention will be more readily understood and appreciated by reference to the detailed description of the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a data recorder.

FIG. 2 is a method for operating the data recorder.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 shows self-contained data recorder 5 for recording rotational velocity and linear acceleration.

Accelerometers 18, 20, 22 are connected by way of filters and gain circuits to analog-to-digital converter (ADC) 16. Accelerometer array 10 contains X-axis linear

accelerometer 18, Y-axis linear accelerometer 20 and Z-axis linear accelerometer 22. The accelerometers are connected by way of filters and gain circuits to analog-to-digital converter (ADC) 16. Linear accelerometers 18, 20, 22 could be three separate accelerometers or a single device providing separate outputs for the X-axis, Y-axis and Z-axis. Each of linear accelerometers 18, 20, 22 provides at least one linear accelerometer output.

Angular sensor array 24 includes roll angular rate sensor 26, pitch angular rate sensor 28 and yaw angular rate sensor 30. Each angular rate sensor 26, 28, 30 provides at least one angular rate sensor output proportional to the angular velocity about its axis. The Gyrostar®, manufactured by Murata Manufacturing Co., Ltd., could be used as such an angular rate sensor.

Accelerometer filter array 12 contains X-axis filter 34, Y-axis filter 36, and Z-axis filter 38. The filters are adjustable for a frequency range from 10-200 Hz. A high frequency setting for the filter allows the recorder to detect small vibrations, while a low frequency setting allows the recorder to detect only large vibrations. The response frequency of each filter is programmed by processor 32 in response to user instructions either stored in memory 40 or sent by way of communication interface 42.

Angular rate filter array 44 contains roll filter 46, pitcher filter 48, and yaw filter 50. Similar to accelerometer filters 26, 28, 30, angular rate filters 46, 48, 50 are adjustable for a frequency range of 10-200 Hz. The angular rate filters are programmable by processor 32 based upon instructions stored in memory 40 or received by way of communication interface 42.

Linear accelerometer gain array 52 and angular rate gain array 54 boosts the signal from the linear accelerometer array 12 to a level sufficient for ADC 16. Linear accelerometer gain array 48 contains three linear accelerometer gain circuits comprising X-axis

gain circuit 56, Y-axis gain circuit 58, and Z-axis gain circuit 60. Angular rate gain array 54 contains roll gain circuit 62, pitch gain circuit 64, and yaw gain circuit 66.

ADC 16 multiplexes the signals from linear accelerometer gain array 46 and angular rate gain array 48 and converts the output to a 10-bit digital value for processor 32. Processor 32 may receive the output from ADC 16 either on separate channels or as multiplexed data through one channel.

Humidity sensor 68 produces a humidity sensor output and temperature sensor 70 produces a temperature sensor output. Humidity sensor 68 and temperature sensor 70 are connected directly to processor 32 if processor 32 has analog inputs. If not, then humidity sensor 68 and temperature sensor 70 would be connected to processor 32 through ADC 16. Clock 72 provides time information to processor 32 so that the length, duration, and time of an event can be recorded. Clock 72 can be used to generate a time stamp of an event.

Memory 40 connected to processor 32 stores the humidity sensor output or the temperature sensor output in memory 40. It may also contain programming information for processor 32, filter arrays 12, 44, and linear accelerometers 18, 20, 22. It also stores time information from clock 72.

Communication interface 42 may be an RS-232 interface, a USB (uniform serial bus) interface, a IrDA (infrared data association) interface , or a wireless communication device. A suitable wireless communication device might include a wireless network adapter or a radio transceiver.

Communication interface 42 allows for information and instructions to be loaded into memory 40 as well as for retrieval of information stored in memory 40. Prior to startup, the linear accelerometers thresholds for each linear accelerometer 18, 20, 22 and the angular rate

thresholds for each angular rate sensors 26, 28, 30 are downloaded to the system through communication interface 42. The maximum time for recording any event is also downloaded through communication interface 42.

Power supply 74 provides power through bus 76 to all active devices within the data recorder needing a power source. Power supply 74 could be regulated by processor 32.

A housing is used to enclose the various parts of self-contained data recorder 5. If X-axis linear accelerometer 18, Y-axis linear accelerometer 20 and Z-axis linear accelerometer 22 are not a single triaxial accelerometer, then they should be positioned within the housing so that each measures linear acceleration along a linear acceleration axis. The three linear accelerometer axes should be substantially orthogonal.

Similarly, the roll angular rate sensor 26, pitch angular rate sensor 28 and yaw angular rate sensor 30 each have an angular rate sensor axis. The roll angular rate sensor axis, pitch angular rate sensor axis and yaw angular rate sensor axis should be substantially orthogonal. Each angular rate sensor axis should be collinear or substantially collinear with one and only one of the linear accelerometer axes.

The orthogonal relationship of the linear accelerometer axes as well as the orthogonal relationship of the rate sensor axes provides the data recorder with the ability to record all movements of the data recorder.

FIG. 2 shows the operation of the recorder. During the configuration, a variety of system variables are set by way of communication interface 42.

At system startup, processor 32 configures the filters in filter arrays 12, 44. Step 100. During the configuration, a variety of system variables are set by way of communication interface 42. Each linear accelerometer and each angular rate sensor can have different settings.

Additionally, the maximum time for recording of any event is set. X-axis threshold value, Y-axis threshold value, Z-axis threshold value, pitch threshold value, roll threshold value, and yaw threshold value are stored in memory 40. A pointer is initialized to point at the first block in memory 40.

After startup, linear accelerometers 18, 20, 22 and angular rate sensors 26, 28, 30 provide signals to the respective filters 34, 36, 38, 46, 48, 50. ADC 16 continually samples the outputs from gain circuits 56, 58, 60, 62, 64, 66 and provides a digital output of the sampling to processor 32. Processor 32 continually stores the output into memory 40. Step 104.

The outputs from linear accelerometers 18, 20, 22 and angular rate sensors 26, 28, 30 are continually compared with the respective thresholds. Step 106. If any threshold is not exceeded, then the sampling continues. Step 104.

If the threshold has been exceeded for any output of linear accelerometers 18, 20, 22 or angular rate sensors 26, 28, 30, the clock output is recorded. Step 108. The outputs from the angular rate sensors 26, 28, 30 and linear accelerometers 18, 20, 22 are recorded. Step 110.

The linear acceleration or gyro velocity are compared to the threshold. Step 112. If the linear acceleration and gyro velocity are below the threshold, then the end of the event is recorded. Step 114. To avoid continual triggering of the system based due to from a previously recorded event, linear accelerometers 18, 20, 22 are re-zeroed. Step 116.

If the linear acceleration and gyro velocity are not below the threshold, then the length of the event is determined. Step 117. If the maximum length of time for an event has been exceeded, then the end of event is recorded and the linear accelerometers are ended. Step 114, 116.

The pointer is then moved to point to the next block in memory. Step 118. The system returns to recording the accelerometer data and the angular rate sensor data. Step 104. The process then repeats.

Processor 32 can also be programmed to provide signals through communication interface 42 if a threshold is exceeded. Thus, the system could be used to start or stop other devices. Information about the humidity and temperature of the device could also be recorded.

The above description is of the preferred embodiment. Various alterations and changes can be made without departing from the spirit and broader aspects of the invention as defined in the appended claims, which are to be interpreted in accordance with the principles of patent law including the doctrine of equivalents. Any references to claim elements in the singular, for example, using the articles "a," "an," "the," or "said," is not to be construed as limiting the element to the singular.